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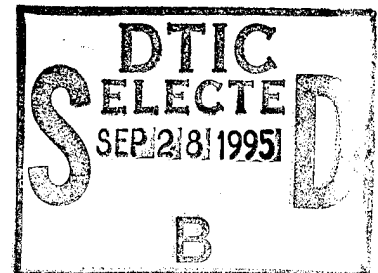
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GRANT No.: N00014-89-J-1754

**THE EFFECTS OF MAGNETIC STORM PHASES ON
F-LAYER IRREGULARITIES
FROM AURORAL TO EQUATORIAL LATITUDES**

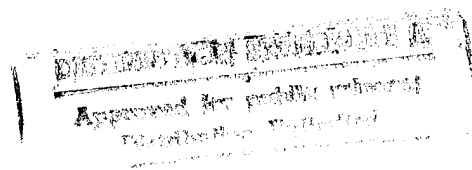
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MIDDLE LATITUDE STUDIES

During this period of time the principal investigators spent contractual time on two problems. One was the completion of a middle latitude paper in preparation for the Beacon Satellite Symposium held in early July in Aberystwyth, Wales. The second was to work on the proposed new study to determine means of forecasting scintillation activity. A presentation was made at Ithaca for the benefit of ONR Personnel. The presentation included a review of past and ongoing studies, by Michael Mendillo, Jules Aarons and Marlene Colerico. Ideas were presented as to possible integrated programs designed to assist in the forecasting of scintillations principally in the region near the magnetic equator.

This review by Johns Hopkins, Cornell University and Boston University and subsequent e mail messages, emerged as the ONR Northeast Consortium with Cornell University and Applied Physics Laboratory as partners with Boston University in a joint program to develop forecasting techniques to aid the users of 250 MHz FLEETSATCOM and AFSATCOM satellites as well as those using the Global Positioning System. These systems have severe restrictions in certain areas under certain conditions.

The technical aspects of the proposal were outlined as follows:

A. ON A PLAN TO DEVELOP PREDICTIVE CAPABILITY FOR EQUATORIAL SCINTILLATION STORMS

THE NORTHEAST ONR CONSORTIUM

Cornell University
Boston University
Applied Physics Laboratory

During the past twenty years our understanding of Equatorial Scintillation Storms (ESS) has reached a considerable maturity. We understand the average occurrence pattern and underlying physics quite well. We also understand many of the processes which create the day to day variability and which are crucial to the development of forecasting techniques. Yet there remains a persistent, illusive quality in predicting degradation of signals propagating through the ionosphere because no one has created a synthesis of this understanding. The purpose of this White Paper is to outline a five year program which brings together the capabilities of the three major ONR groups in the Northeast for a cooperative venture to predict ESS on time scales of 3-6 hours.

Our program will concentrate on two quite diverse longitude sectors, the severe sea-mountain interface region of Peru wherein the Jicamarca Radio Observatory and its associated instrumentation are located, and the South Pacific region (Kwajalein) located in the Inter-tropical Convergence Zone. These two sectors have already been intensely studied and have existing instrumentation which will make the proposed study very cost-effective.

ESS originates from a post sunset plasma analog to the Raleigh-Taylor instability (sometimes called equatorial spread-F) whose physics is well understood. At GPS frequencies the daily variations of attendant scintillations range from a low of 0 dB to a high of 20-30 dB over the

latitude range of ± 15 degrees. A forecasting plan is outlined in broad brush strokes in the next paragraphs based on our physical understanding. More details and justification of the scientific and technological basis can be made available on request and will be included in our individual proposals. In our opinion the four most important aspects which lead to the day to day variability of ESS are (1) the magnitude and duration of the pre-reversal enhancement of the eastward electric field in the sunset ionosphere; (2) the magnitude and variability of meridional neutral winds and the ionospheric asymmetries they drive (e.g., the ratio of the plasma content between the southern and northern hemispheres in this same time period); (3) the level of atmospheric gravity wave activity in the thermosphere and the structure it induces in the ionosphere; and (4) the penetration of electrical activity from the high latitude zone when the region 1 and region 2 currents are out of balance. Our combined groups are uniquely qualified to undertake this study since we have pioneered the experimental tools needed to address this effort and have applied them to the very problems we wish to study in several dozens of refereed articles, several Encyclopedia articles and a book on Ionospheric Physics.

Years 1 and 2:

A large body of existing data sets obtained in the Peruvian Sector (Jicamarca Radio Observatory and Arequipa Optical Facility) have never been analyzed from the perspective of creating a short term predictive capability. Our initial effort will be to coordinate the analysis of these ionospheric and related magnetospheric observations and apply results to our forecasting goals for ESS. To test the predictive capabilities that emerge, and to obtain new data sets optimized for use in predictive models, a series of campaign mode studies will be conducted.

- A GPS receiver and geostationary satellite polarimeters will be integrated into the day to day operation of data acquisition (CU/BU).
- The continuously operating JULIA system will be modified to provide continuous measurements of the zonal electric field (Clemson/Cornell).
- Airglow capabilities at Arequipa will be modified to allow the plasma content to be modeled on both ends of the field lines threading the region (BU).
- Existing Digital and scintillation data will be integrated into the system to yield a quantitative measure of the ESS activity (BU/Cornell).
- A measure of the imbalance of the region1/region2 currents will be developed (APL).
- A forecasting technique will be developed from the above instrumentation and data sets to define ESS variability in this longitude sector (ABC).

Year 3-5:

The South Pacific Sector will be instrumented while we continue to develop predictive techniques from the Peruvian campaign.

- Either existing or new GPS receivers will be fielded in the sector and this system will be extended to permit tomographic capability (Cornell/BU).

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- A portable 50 MHz system will be installed on the island of Kosare to provide zonal electric field data (Clemson/Cornell)
- Airglow capability will be installed on several islands with the capability to allow the plasma content to be determined on both ends of the field lines threading the region (BU).
- ALTAIR radar observations of equatorial F-region structure and plasma drifts will be made to define the geomagnetic flux tube quantities that determine ESS occurrence (BU)
- APL will continue to provide a measure of the imbalance in region1/region2 currents.
- The above instrumentation and data sets will be combined to develop a forecasting technique and this technique will be compared with the previously developed technique for the Peruvian Sector to establish differences due to local generation of gravity waves. (ABC)

B. MIDDLE LATITUDE STUDIES

A brief summary of the paper presented and authored by J. Aarons at the Satellite Beacon Symposium in Aberystwyth, Wales is as follows:

MID-LATITUDE F LAYER IRREGULARITIES FOR TWO LONGITUDINAL REGIONS INTRODUCTION

The most intense effects of ionospheric irregularities takes place in the anomaly region of the magnetic equator. This region which is a few degrees wide and is located plus or minus 15 degrees from the magnetic equator shows serious fading on 4 GHz trans-ionospheric signals from satellites.

High levels of scintillation are observed in the auroral and polar regions. Magnetic storms and interplanetary magnetic field variations produce high levels of activity in the auroral region.

Even if less severe in intensity, the middle latitudes also experience effects as measured by the ionosondes, satellite scintillation, and in situ observations. We shall present observations at middle latitudes for two longitudinal regions.

1. THE LONGITUDINAL REGION OF 750 WEST

For middle latitude irregularities, it is important to separate three different causes of F layer irregularities. These are the descent of auroral effects to low latitudes, the effects of high altitude equatorial plumes beyond what is considered the anomaly region and finally uniquely middle latitudes mechanisms.

High latitude studies have shown that magnetic storm effects descend to lower latitudes during many magnetic storms. Scintillation observations taken in the Boston area and in Puerto Rico have shown the descent and weakening of the effects of the magnetic storm. Middle latitudes were affected.

Taking scintillation observations from Puerto Rico, which is polewards of the equatorial anomaly region (and is considered lower mid-latitude), the data showed that occurrence and peak levels reached maxima in the solstices. These scintillations are not tied to equatorial irregularities,

since on the magnetic equator near the 750 West longitude region, the occurrence of F layer irregularities as observed in Huancayo, Peru (Aarons, 1993) is high in equinoctial months and almost non-existent in June and July.

2. MID-LATITUDE E AND F LAYER NORTHERN SUMMER IRREGULARITIES AT 110-1300 EAST

A review of the spread F literature indicates that several authors have found that maximum activity at middle latitudes took place during years of low solar flux. Again one must look for effects of the high latitude effects descending to lower latitudes and the equatorial latitude effects extending into middle latitudes.

2a. EQUATORIAL EFFECTS

Plumes reaching high altitudes at equatorial latitudes indicate the range of effects produced was beyond what is considered the normal equatorial anomaly region.

The recent studies of the height of the depletions (depletions are correlated with F-layer irregularities) indicate that the height of the plume irregularities was considerably above that previously known (1000 km) (Sahai, et al, 1994). The altitudes reached as indicated by the Brazilian measurements were greater than 1500 Km and went as high as 2500 km. This indicated effects somewhat beyond the anomaly region. This height did not change with lower solar flux (however the background electron density did).

A unique opportunity presented itself to compare irregularity activity along a relatively narrow range of longitudes but at different latitudes. This included several stations near 120-1300 East. These were scintillation observations at 136 MHz during both high and low solar flux years. At the levels that can be noted (peak to peak excursions of 15-20 dB) there is considerable activity.

Three locations i.e. Manila, the Philippines, Lunping, Taiwan and Osan, Korea were used for the longitudinal studies. Manila is located near the magnetic equator (intersection of 40 dip latitude) The Lunping intersection to ETS-2 satellite is in the anomaly region. Osan is located above the anomaly region at a dip latitude of 29.5 degrees. There was little correlation of the Manila and Lunping data with data from Osan, Korea during the months of May-July.

The morphology of equatorial latitude F layer irregularities is reasonably well known. For Manila equatorial irregularities exist predominantly in the equinoctial months with a lowered occurrence in May-August and with almost no occurrence November-January.

The high occurrence of Northern Summer scintillation as shown in the Osan data indicates that the mechanisms for the generation for these middle latitude irregularities differs from the mechanism responsible for scintillations at the equator. The "lower" middle latitudes i.e. polewards of the equatorial anomaly region indicates an independent mechanism for the generation of irregularities.

3. SPORADIC E AND F LAYER IRREGULARITIES

For this latitude region, there is evidence to show that there is at times a strong connec-

tion between sporadic E and F-layer irregularities. Scintillation readings integrate irregularity scattering from both the E and F layers. Therefore the scintillation data linking sporadic E and spread F has to be supplemented by variations in total electron content and sounder observations to separate the variables.

This will be investigated further but it is unlikely that sporadic E is responsible for the long lasting nighttime occurrence of irregularities with its large fluctuations in total electron content.

C. THE ONR SPONSORED ALL-SKY IMAGER

The ONR sponsored All-Sky Imager is now operating in Goose Bay, observing at 6300 Å. Monitoring of the equipment and data is being done from Boston University in Boston. At the present time data is being taken continuously at night at Goose Bay.

D. THE ONR AASERT PROGRAM IN UPPER ATMOSPHERE AND IONOSPHERIC PHYSICS

Ms. Marlene Colerico started her AASERT fellowship in August 1993 and is now a full-time graduate student in the Electrical, Computer and Systems Engineering M.S. program while being a graduate research assistant in the Center for Space Physics. In March, 1994 Ms. Colerico helped to install an all-sky imaging system at Goose Bay, Labrador. During the period April 1, 1994 - June 30, 1994, we received the first installment of data taken with the Goose Bay imager. This installment included data from the March and April operation cycles. She has begun a preliminary analysis of the data. The analysis included cataloging and characterization of the data by date, time, weather conditions, and activity (aurora, SAR arcs). The field of view of the Goose Bay imager overlaps with the fields of view of the Millstone Hill and Sondrestrom imagers. A comparison of the Goose Bay Imager data and the Millstone Hill Imager data has begun. Ms. Colerico presented an example of such a comparison at the ONR meeting held at Cornell on July 1, 1994. In addition to this study Ms. Colerico has also been working on the analysis of data taken with the Boston University Imager at Arequipa, Peru. She found several cases of airglow depletions which cause scintillations. In addition, she has calculated the velocity with which these airglow depletions move through the field of view. Preliminary results from this data set were also presented at the ONR meeting.

E. PUBLICATIONS

The paper "The Sunspot Cycle and Auroral F Layer Irregularities" by J. Aarons, L. Kersley (University College of Wales) and A.S. Rodger (British Antarctic Survey) which was published in an earlier form in the Proceedings of the Ionospheric Effects Symposium has been accepted by *Radio Science*.

The paper "The Altitude-Latitude Extent of Equatorial Plasma Depletions" by M. Mendillo

was published in the Proceedings of the COSPAR Colloquium on Low Latitude Ionospheric Physics.

The paper on "OI 630 nm imaging ..", referred to in previous ONR quarterly reports, has appeared in the Journal of Atmospheric Physics v 56, 1461-1475, 1994